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The Temporal Dynamics of Directed Reappraisal in High-Trait-Anxious Individuals

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High-trait-anxious (HTA) individuals often experience high levels of negative emotions, signaling potential abnormalities in the down-regulation of negative emotions. In this study, we used event-related potentials to examine whether HTA individuals can effectively use directed reappraisal to down-regulate negative emotions. Participants completed a passive picture-viewing task in which pictures were preceded by audio descriptions of their content. For unpleasant pictures, descriptions were either neutral or negative, whereas for neutral pictures, only neutral descriptions were given. Self-report behavioral results indicated that HTA individuals reported greater unpleasantness for the pictures than did low-trait-anxious (LTA) individuals but revealed no abnormality in decreasing negative emotional experience. Such abnormality, however, did emerge neurally. Analyses focused on the central-parietal late positive potential (LPP), a neural marker of emotion regulation. LTA individuals showed an LPP reduction in response to unpleasant pictures with negative descriptions compared to neutral ones at 400–3000-ms post-picture-onset, indicating effective down-regulation of negative emotions. HTA individuals, however, showed no LPP reduction at 400- to 1,000-ms post picture onset. Instead, they showed an LPP increase in response to unpleasant pictures with negative descriptions compared to neutral ones at 1,000- to 2,000-ms post picture-onset. These abnormal central-parietal LPP patterns not only verify that HTA individuals exhibit ineffective use of directed reappraisal to down-regulate neural responses to unpleasant stimuli, but also reveal an abnormal time-course of directed reappraisal in such individuals. Our findings also suggest that the ineffective use of cognitive reappraisals may contribute to the generally elevated levels of negative emotionality in HTA individuals.

Keywords: trait anxiety, emotion regulation, reappraisal, late positive potential (LPP)

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Human life is suffused with emotion, such as the joy of success, the sadness of failure, and the fear of threat. The generation of emotion is not a passive process, as we can actively modify the subjective, behavioral, and physiological aspects of emotions; this process of modifying emotion has been termed *emotion regulation* (Gross, 2014). Successful emotion regulation is conducive to social functioning, creativity, and subjective well-being (Eisenberg, Fabes, Guthrie, & Reiser, 2000; Gross & John, 2003; Hoffmann & Russ, 2012). Conversely, emotion dysregulation is closely related to interpersonal conflicts, social aggression, and anxiety disorders (Amstadter, 2008; Cisler & Olatunji, 2012). Therefore, from a mental health standpoint, it is of great importance to examine whether certain clinical or high-risk individuals can successfully implement emotion regulation.

With respect to individual differences in emotion regulation, previous studies have mainly focused on abnormalities in patients with anxiety disorders (Ball, Ramsawh, Campbell-Sills, Paulus, & Stein, 2013; Goldin, Manber, Hakimi, Canli, & Gross, 2009; New et al., 2009), with high-trait-anxious (HTA) individuals tending to fall outside of the spotlight. Given that HTA individuals often report experiencing higher levels of negative emotions toward a broader range of situations than do other people (Spielberger, 1979), extending empirical research on emotion regulation to this population is warranted. Furthermore, given that HTA is a well-established risk factor for the development of anxiety disorders (Indovina, Robbins, Nunez-Elizalde, Dunn, & Bishop, 2011), studies on emotion regulation of HTA individuals would complement those on patients with anxiety disorders, and would be helpful in identifying the underlying mechanisms of HTA's risk for anxiety illnesses.

One study, using functional MRI (fMRI), has provided preliminary insight into the neural substrates of cognitive reappraisals in HTA individuals (Campbell-Sills et al., 2011). Cognitive reappraisal, an extensively studied emotion regulation strategy, can help people alter their emotional responses through reinterpretation of the meaning of a stimulus (Sheppes & Gross, 2011). Campbell-Sills et al. (2011) found that reappraisal of negative pictures activated greater lateral prefrontal cortex (PFC) responses but comparable amygdala responses in HTA individuals compared to healthy controls, suggesting that HTA individuals require greater top-down control to accomplish down-regulation of negative emotions. Although the fMRI study by Campbell-Sills et al. (2011) identified brain activation patterns, it was unable to capture the temporal dynamics of cognitive reappraisal in HTA individuals. Event-related potentials (ERPs) would be useful in this regard because of their excellent temporal resolution.

Indeed, ERP research has provided a well-validated electrophysiological index of emotion regulation—the central-parietal late positive potential (LPP; Hajcak, Dunning, Foti, & Weinberg, 2014; Hajcak, MacNamara, & Olvet, 2010; Moser, Hartwig, Moran, Jendrusina, & Kross, 2014). The central-parietal LPP appears around 300 ms after stimulus onset and sustains throughout the stimulus presentation. The amplitude of the central-parietal LPP is larger for both unpleasant and pleasant stimuli than for neutral stimuli (Schupp et al., 2000). On the basis of its functional significance, the central-parietal LPP can be classified as the early central-parietal LPP (300 to 1,000 ms) or the late central-parietal LPP (>1,000 ms). The early central-parietal LPP can be considered to reflect attention allocation to emotionally arousing stimuli, whereas the late central-parietal LPP reflects more sustained and elaborative processing of stimulus meaning (Hajcak, Dunning, Foti, & Weinberg, 2014; Hajcak, MacNamara, & Olvet, 2010; Moser et al., 2014; Strauss et al., 2013). Furthermore, a substantial body of literature has indicated that the central-parietal LPP is sensitive to emotion regulation strategies, such as distraction (Schonfelder, Kanske, Heissler, & Wessa, 2014; Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011), cognitive reappraisal (Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; Moser, Hajcak, Bukay, & Simons, 2006; Moser et al., 2014), and expressive suppression (Paul, Simon, Kniesche, Kathmann, & Endrass, 2013).

To date, however, only one ERP study (using a correlational approach) has examined whether worry, or anxious apprehension, modulates reappraisal-related ERPs (Moser et al., 2014). Moser et al. (2014) reported that worry was associated with greater preparatory activity and attention allocation during positive reappraisal relative to passive viewing of negative pictures, as reflected by enhanced frontal stimulus preceding negativity (SPN) and the early central-parietal LPP (400 to 1,000 ms). Moreover, worry was not associated with decreases in the later central-parietal LPP (Moser et al., 2014). However, both Campbell-Sills et al. (2011) and Moser et al. (2014) used a self-generated reappraisal task, wherein reappraisal was more difficult or cognitively demanding than was passive viewing because participants had to generate their own reinterpretations to decrease the negative emotions in the reappraisal condition. Given the increased PFC activation and enhanced frontal SPN and early central-parietal LPP in response to cognitively demanding tasks (Basten, Stelzel, & Fiebach, 2011; Matsuda & Nittono, 2015; Rypma, Berger, & D'Esposito, 2002; Seidel et al., 2015) and less habitual use of cognitive reappraisal in anxious individuals (Amstadter, 2008), these enhanced activations might merely reflect the increased task difficulty of generating reinterpretations. Accordingly, the lack of a decrease in amygdala response in HTA individuals (Campbell-Sills et al., 2011) or the late central-parietal LPP in worriers (Moser et al., 2014) might be attributed to their inability to generate reinterpretations rather than their inability to alter the meaning of the negative stimuli via reappraisal.

To overcome the limitations of the self-generated reappraisal task, we used Foti and Hajcak's (2008) directed reappraisal task. In their study, participants passively viewed unpleasant or neutral pictures preceded by audio descriptions (Foti & Hajcak, 2008). For unpleasant pictures, these descriptions were either neutral or negative, whereas for neutral pictures, only neutral descriptions were used. For example, the audio descriptions of an unpleasant image depicting a snake either said "This snake is harmless and is in a zoo exhibit" (neutral description) or "This poisonous snake is about to attack" (negative description). The descriptions serve as "reappraisal frames" that guide people's initial appraisal of each picture. This preappraisal manipulation removes the potential confound of task difficulty, such that participants simply listen to audio descriptions and then view pictures in each condition (Foti & Hajcak, 2008; MacNamara, Foti, & Hajcak, 2009). Therefore, the directed reappraisal task is likely better suited for investigating cognitive reappraisal success independently of personal ability to generate reinterpretations for unpleasant stimuli. Furthermore, in this directed reappraisal task, the central-parietal LPP for unpleasant pictures was found to be smaller when preceded by neutral descriptions than when preceded by negative ones, evidencing an effective down-regulation of negative emotion during directed reappraisal (Foti & Hajcak, 2008; Horan, Hajcak, Wynn, & Green, 2013; Strauss et al., 2013). Thus, the utility of the central-parietal LPP could assist us in revealing the temporal dynamics of directed reappraisal in HTA individuals.

To extend the literature on cognitive reappraisal in HTA individuals, this study used ERPs to examine whether HTA individuals can effectively use directed reappraisal to down-regulate neural responses to negative stimuli and the temporal dynamics of this process. We tested two main hypotheses. On the basis of previous ERP evidence for effective emotion regulation via the use of directed reappraisal (Foti & Hajcak, 2008; Horan et al., 2013; MacNamara et al., 2009; Strauss et al., 2013), the first hypothesis was that low-trait-anxious (LTA) individuals would display smaller LPP amplitudes in response to unpleasant pictures that are preceded by neutral descriptions relative to negative descriptions. In contrast, HTA individuals were expected to show an abnormal use of directed reappraisal—they would not show the decreased LPP for unpleasant pictures when preceded by neutral descriptions relative to negative descriptions. There are two reasons for the impaired cognitive reappraisal in HTA individuals. First, cognitive reappraisal involves reinterpreting the meaning of negative stimuli in a positive way; however, HTA individuals are prone to interpret emotionally ambiguous stimuli or moderate negative stimuli as more negative than are LTA individuals (Bishop, 2007; Blanchette & Richards, 2003; Gebhardt & Mitte, 2014). Negative interpretation biases thus may result in automatic mood-congruent interpretations of potentially negative stimuli, which would in turn make it difficult for HTA individuals to view stimuli from a positive perspective. Second, the ability to employ top-down processing to control emotional responses is crucial for successful cognitive reappraisal, as both directed and self-generated reappraisals recruit prefrontal control mechanisms to modulate emotional responses in the amygdala (Buhle et al., 2014; Mocaiber et al., 2011; Ochsner & Gross, 2005); however, HTA individuals are associated with impaired cognitive control, even in the absence of threatening information (Bishop, 2009; Bishop, Duncan, Brett, & Lawrence, 2004; Qi, Ding, & Li, 2014). Impaired recruitment of cognitive control mechanisms therefore may disturb HTA individuals to down-regulate negative emotions via use of directed reappraisal. In addition, there is evidence that self-generated reappraisals are associated with enhanced cue-locked SPN (indexing anticipation and preparatory activity) and enlargement of the frontal LPP (reflecting increased cognitive effort; Moser et al., 2014). Given the lack of evidence regarding the SPN and frontal LPP in the directed reappraisal task, we explored whether increased SPN and frontal LPP amplitudes would occur in response to unpleasant pictures preceded by neutral descriptions relative to negative ones, particularly for the LTA group.

Regarding emotion effects, prior studies have showed that anxious individuals exhibit attentional avoidance of negative stimuli at later stages of a passive picture-viewing task (Holmes, Nielsen, & Green, 2008; Weinberg & Hajcak, 2011). Thus, the second hypothesis was that both HTA and LTA groups would be sensitive to the emotional arousal of the stimuli, but the HTA group would show reduced elaborative processing of unpleasant pictures at later stages. Specifically, both groups would display larger LPP amplitudes to negatively described unpleasant pictures compared with neutral pictures; however, the LPP differences between the two conditions would be smaller in the HTA group.

Method

Subjects

Initially, 1,500 undergraduate students from Shaanxi Normal University, China, took part in a pretest comprising a mass screening of trait anxiety using the Chinese version of the trait anxiety portion of the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983; Shek, 1993). Participants who scored high in trait anxiety (HTA group; upper 27th percentile of the distribution) or who had particularly low levels of trait anxiety (LTA group; lower 27th percentile of the distribution) were selected for further consideration. From these groups, we invited 20 female HTA participants ($M = 19.50$ years, $SD = 1.28$) and 20 female LTA participants ($M = 18.70$ years, $SD = 0.92$) to take part in the study. Only females were chosen to control for any gender differences in cognitive reappraisal (Domes et al., 2010). Additionally, as most classes in Shaanxi Normal University are dominated by female students, there was an insufficient number of male participants in the mass screening for a balanced gender distribution in our sample. All participants were tested within 2 weeks of the pretest. Before the EEG testing session, each participant provided their demographic information (see Table 1) and was again administered the trait anxiety scale of the STAI and the Chinese version of the Beck Depression Inventory (BDI-II; Beck, Steer, Ball, & Ranieri, 1996) as posttest. An independent samples t test (two-tailed) showed that the HTA group had significantly higher trait anxiety scores than did the LTA group at both test times; pretest: $t(38) = 26.35$, $p < .001$; posttest: $t(38) = 15.82$, $p < .001$. All participants were right-handed and had normal or corrected-to-normal vision. None had a history of psychiatric or neurological disorders, as assessed by self-report in a telephone interview. Prior to the experiment, they reported no use of medication or other nonmedical substances that could potentially affect the central nervous system.

Stimulus and Procedure

In an electromagnetically shielded room, the participants were seated comfortably about 1 m away from a 24-in. screen. They performed a directed reappraisal task adapted from Foti and Hajcak (2008) in which participants passively viewed a series of

Table 1
Demographic Information for the High-Trait-Anxious (HTA) and Low-Trait-Anxious (LTA) Groups

	Trait anxiety score			
	Pretest	Posttest	BDI[a] score	Age
Group	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
HTA	61.75 (4.95)	59.05 (6.66)	21.80 (9.27)	19.50 (1.28)
LTA	27.80 (2.95)	30.15 (4.73)	4.80 (3.21)	18.70 (.92)

Note. BDI = Beck Depression Inventory-II (Beck, Steer, Ball, & Ranieri, 1996).
[a] We used the Chinese version of the BDI.

unpleasant or neutral pictures. Each picture was preceded by an audio description of its content. These audio descriptions were created by a speech synthesis tool (see http://www.3987.com/xiazai/4/109/38579.html). A total of 84 pictures (28 neutral and 56 unpleasant) were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). All pictures were assessed using a 9-point scale in terms of valence (1 = *pleasant*, 9 = *unpleasant*) and arousal (1 = *low*, 9 = *high*) by a separate group of 24 female participants (M_{age} = 19.21 years, SD = 1.06). The two categories differed significantly in terms of valence (neutral pictures: M = 5.61, SD = 0.41; unpleasant pictures: M = 2.07, SD = 0.49), $t(23) = 25.82$, $p < .001$, and arousal ratings (neutral pictures: M = 5.03, SD = 1.23; unpleasant pictures: M = 7.15, SD = 0.79), $t(23) = -13.68$, $p < .001$. A complete list of the IAPS picture numbers and associated descriptions are presented in Tables S1 and S2 of the online supplementary material.

Each trial started with a white fixation cross presented on a black screen for 0.5 s. The fixation cross disappeared while an audio description was played for 3 s to 5 s. Then, following another fixation for 1 to 1.5 s, a full-screen picture was displayed for 3 s. After the offset of each picture, unlimited time was allowed to rate the picture in terms of dimensions of valence on the 9-point scale. The intertrial interval was 1 s.

There were three conditions differing in the emotional valence of descriptions and pictures. In the neutral condition, neutral descriptions were used for the 28 neutral pictures. In the preappraised negative condition, negative descriptions were used for the 28 negative pictures. Finally, in the preappraised neutral condition, neutral descriptions were used for the 28 negative pictures. Overall, each participant performed 84 trials, with a break every 21 trials. The order of trials and the type of description that preceded each unpleasant picture were arranged randomly for each participant.

EEG Recording and Processing

Brain electrical activity was recorded at 64 scalp sites using Ag/AgCl electrodes and referenced to the left mastoid, with a ground electrode on the medial frontal aspect. The vertical electrooculogram (EOG) was recorded supra- and infraorbitally at the left eye; the horizontal EOG was recorded from the left versus the right orbital rim. The EEG and EOG were amplified by a SynAmps2 amplifier (Neuroscan, Herndon, VA, USA) and were continuously digitized at 500 Hz/channel with a bandpass filter of DC to 100 Hz. All interelectrode impedances were maintained below 5 kΩ.

Offline analyses were performed in Matlab using the EEGLAB (Delorme & Makeig, 2004) and ERPLAB toolboxes (Lopez-Calderon & Luck, 2014). Data preprocessing included the removal of large muscle artifacts or extreme offsets (which were identified by visual inspection). Then, all EEG-data were re-referenced to the average of all electrodes and filtered using Butterworth filters with half-power cutoffs at 0.05 and 36 Hz (roll-off = 12 dB/octave). Independent component analysis (ICA) was subsequently performed for each subject to remove components that were clearly associated with eye movements and eye-blink activity (Jung et al., 2000). The ICA-corrected EEG data were segmented into epochs. Baseline correction was performed by subtracting the mean of the 500-ms predescription or prepicture period. Any epochs with EEG voltages exceeding the threshold of ± 100 μV were excluded from the average. The percentages of trials excluded from averaging due to artifact detection were 13.5% for the LTA group and 12.2% for the HTA group.

The ICA-corrected EEG data were segmented into epochs that began 500 ms before onset of the audio description and continued to 5,000 ms for the SPN analysis. Separate averages were computed for each participant for each type of description (neutral description, preappraised neutral description, preappraised negative description). On the basis of previous studies (Moser et al., 2014; Thiruchselvam et al., 2011), the SPNs were quantified as the average activity collapsed across the three frontal electrodes (F1, Fz, F2) within the time window of 3,000 to 5000 ms. The resulting SPN amplitudes were entered into separate 3 (Description Type: neutral description, preappraised neutral description, and preappraised negative description) × 2 (Group: HTA and LTA) repeated-measures analyses of variance (ANOVAs).

With respect to the LPP, EEG data were segmented into epochs that began 500 ms before the onset of the picture and continued for 3000 ms. Separate averages were computed for each participant in each of the three experimental conditions (neutral, preappraised neutral, preappraised negative). On the basis of previous studies (Foti & Hajcak, 2008; Horan et al., 2013; Moser et al., 2014; Strauss et al., 2013) and the morphology of the current waveforms, the frontal LPPs were quantified as the average activity collapsed across three electrodes (F1, Fz, F2) at 700 to 1,100 ms post picture onset; the central-parietal LPPs were quantified as the average activity collapsed across five electrodes (Cz, CP1, CPz, CP2, Pz) at three time windows: (1) 400 to 1,000 ms, (2) 1,000 to 2,000 ms, and (3) 2,000 to 3,000 ms. These three time windows for the central-parietal LPP were selected on the basis of the differential functional significance of the early and late central-parietal LPPs (Hajcak et al., 2014; Hajcak, MacNamara, & Olvet, 2010; Moser et al., 2014; Strauss et al., 2013). The resulting LPP amplitudes were entered into separate 3 (Condition: neutral, preappraised neutral, and preappraised negative) × 2 (Group: HTA and LTA) repeated-measures ANOVAs for each window. All ANOVA results were subjected to the Greenhouse-Geisser correction if the assumption of sphericity was violated.

Results

Behavioral Data

For valence ratings, repeated-measures ANOVAs showed no significant Group × Condition interaction, $F(2, 76) = 0.16$, $p = .84$, $\eta_p^2 = .004$; however, a significant main effect of condition was observed, $F(2, 76) = 276.02$, $p < .001$, $\eta_p^2 = .879$. As shown in Figure 1A, both groups demonstrated a linear decrease across conditions, with the valence ratings being highest in the neutral condition (M = 5.47, SD = 0.52), intermediate in the preappraised neutral condition (M = 3.69, SD = 0.83) and lowest in the preappraised negative condition (M = 2.22, SD = 0.61), $ts > 9.8$, $ps < .001$. This suggests that neutral descriptions made participants feel less unpleasant in response to negative pictures than did negative descriptions. Most strikingly, a significant main effect of group was observed, $F(1, 38) = 5.93$, $p = .02$, $\eta_p^2 = .135$, indicating that the HTA group (M = 3.63, SD = 0.46) reported

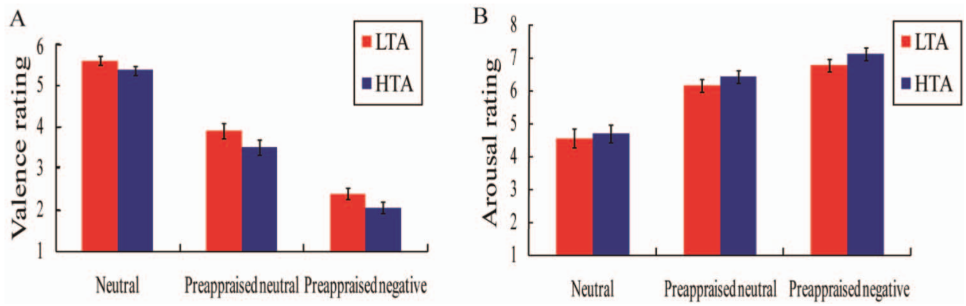

Figure 1. Mean valence and arousal ratings in response to stimuli for the high-trait-anxious (HTA) and low-trait-anxious (LTA) groups. Error bars represent standard errors of the means. See the online article for the color version of this figure.

more unpleasantness in response to the pictures than did the LTA group ($M = 3.95$, $SD = 0.37$) across all conditions.

For arousal ratings, repeated-measures ANOVAs showed a significant main effect of condition, $F(2, 76) = 150.22$, $p < .001$, $\eta_p^2 = .798$; however, both the main effect of group, $F(1, 38) = 0.83$, $p = .37$, $\eta_p^2 = .021$, and the Group × Condition interaction, $F(2, 76) = 0.34$, $p = .67$, $\eta_p^2 = .009$, were nonsignificant. As can be seen in Figure 1B, both groups showed a similar pattern of arousal ratings, whereby the preappraised negative condition ($M = 6.95$, $SD = 0.83$) was rated as more arousing than was the preappraised neutral condition ($M = 6.28$, $SD = 0.90$), which in turn was more arousing than the neutral condition ($M = 4.62$, $SD = 1.23$), $ts > 6.5$, $ps < .001$.

ERP Data

SPN. Figure 2 shows the waveforms of frontal SPN elicited by audio descriptions for the LTA and HTA groups. A repeated-measures ANOVA on SPN amplitudes showed a significant main effect of description type, $F(2, 76) = 8.37$, $p = .001$, $\eta_p^2 = .18$; however, both the main effect of group, $F(1, 38) = 0.03$, $p = .87$, $\eta_p^2 = .001$, and the Group × Description Type interaction, $F(2, 76) = 0.29$, $p = .75$, $\eta_p^2 = .007$, were nonsignificant. As can be seen in Figure 2, both groups showed a similar pattern of SPN amplitudes, where the SPN was significantly larger for both neutral ($M = -4.69$, $SD = 3.03$) and negative ($M = -4.53$, $SD = 2.78$) descriptions for negative pictures compared with neutral descriptions for neutral pictures ($M = -2.66$, $SD = 2.98$), $ts > 3.38$, $ps < .002$. The difference between neutral and negative descriptions for negative pictures was nonsignificant, $t(39) = -0.30$, $p = .77$.

Frontal LPP. Figure 3 shows the waveforms of the frontal LPP elicited by pictures for the LTA and HTA groups. A repeated-measures ANOVA on frontal LPP amplitudes showed a significant main effect of condition, $F(2, 76) = 7.13$, $p = .002$, $\eta_p^2 = .158$; however, both the main of group, $F(1, 38) = 0.001$, $p = .98$, $\eta_p^2 < .001$, and the Group × Condition interaction, $F(2, 76) = 0.47$, $p = .62$, $\eta_p^2 = .012$, were nonsignificant. As can be seen in Figure 3, both groups showed a similar pattern of frontal LPP amplitudes, where the frontal LPP was significantly larger in both the preappraised neutral ($M = 3.74$, $SD = 3.41$) and preappraised negative ($M = 3.30$, $SD = 4.09$) conditions compared with the neutral condition ($M = 2.13$, $SD = 3.60$), $ts > 2.46$, $ps < .02$. Additionally, the two preappraised conditions did not differ from each other, $t(39) = 1.01$, $p = .32$.

Central-parietal LPP. Figure 4 depicts the waveforms of central-parietal LPP elicited by pictures for the LTA and HTA groups. To follow up on the significant interactions and directly test the hypothesized emotion regulation effects in each group, paired-samples t tests (two-tailed) were conducted. In addition, to

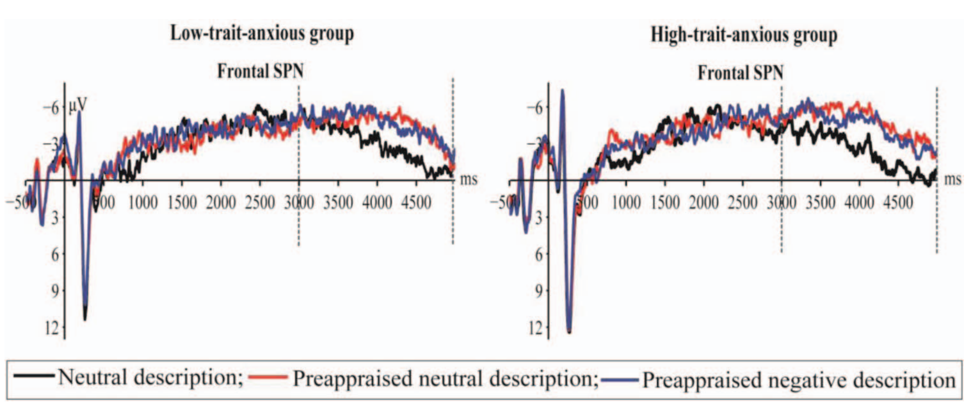

Figure 2. Audio descriptions-locked enhanced frontal stimuli preceding negativity (SPNs) averaged at three frontal sites (F1, Fz, F2) for low-trait-anxious group (left) and high-trait-anxious group (bottom) in each description type. See the online article for the color version of this figure.

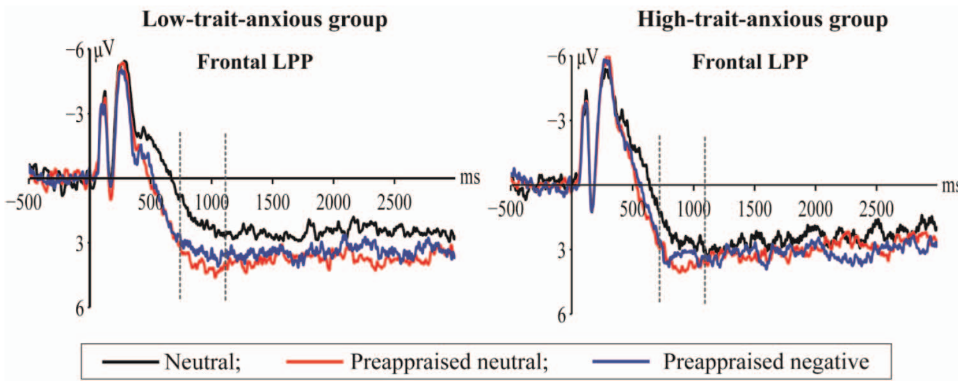

Figure 3. Picture-locked late positive potentials (LPPs) averaged at three frontal sites (F1, Fz, F2) for low-trait-anxious group (left) and high-trait-anxious group (bottom) in each condition. See the online article for the color version of this figure.

test differences in hypothesized emotion effects between the groups, independent-samples t tests (two-tailed) were conducted.

Central-parietal LPP (400 to 1,000 ms). For the central-parietal LPP amplitudes during the time window of 400–1000 ms, both the main effects of condition, $F(2, 76) = 84.18$, $p < .001$, $\eta_p^2 = .689$, and the Group × Condition interaction, $F(2, 76) = 4.18$, $p = .019$, $\eta_p^2 = .099$, were significant. For the LTA group, the amplitudes of the central-parietal LPP were higher for both the preappraised negative and the preappraised neutral conditions than for the neutral condition (ts > 6.10, ps < .001), and the amplitude of the preappraised negative condition was higher than was that of the preappraised neutral condition, $t(19) = 4.40$, $p < .001$. These findings indicate that directed reappraisal successfully down-regulated the early neural response to unpleasant stimuli in the LTA group. The HTA group also showed higher central-parietal LPP amplitudes in both the preappraised negative and the preappraised neutral conditions than in the neutral condition (ts > 6.58, ps < .001); however, there was no difference between the two preappraised conditions, $t(19) = 0.38$, $p = .71$, suggesting that the HTA group was unable to effectively down-regulate the early neural response to unpleasant stimuli (see Figure 5).

In addition, to examine group differences in central-parietal LPP amplitudes at each condition, independent samples t tests (two-tailed) were conducted between the HTA and LTA groups. During the time window of 400 to 1,000 ms, intergroup comparisons showed a more positive central-parietal LPP for the HTA group

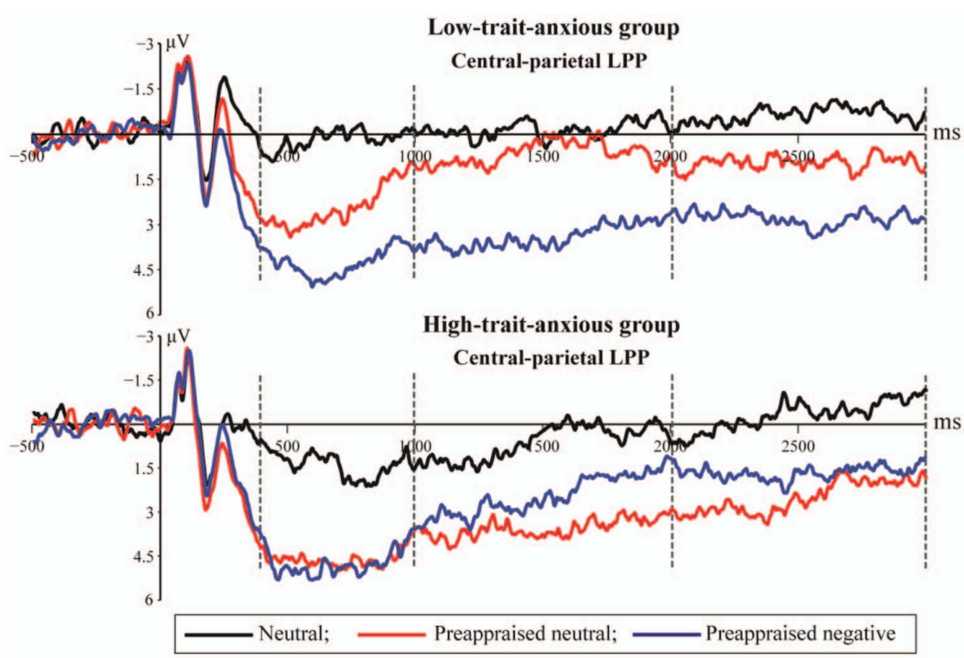

Figure 4. Picture-locked late positive potentials (LPPs) averaged at five centro-parietal sites (Cz, CP1, CPz, CP2, and Pz) for low-trait-anxious group (top) and high-trait-anxious group (bottom) in each condition. See the online article for the color version of this figure.

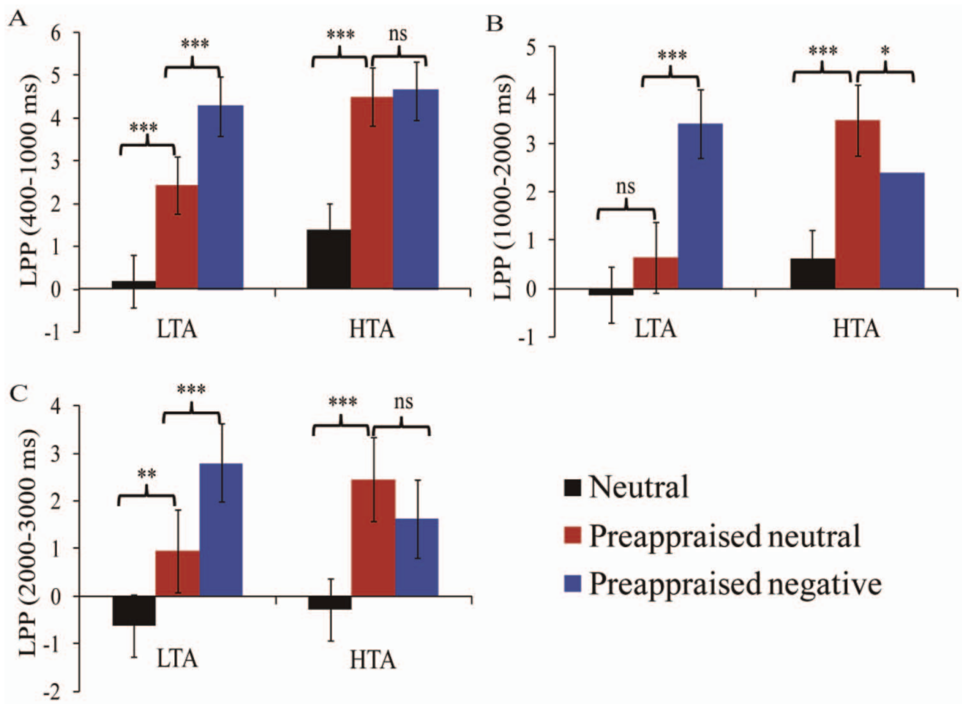

Figure 5. Mean central-parietal late positive potential (LPP) amplitudes at each time windows: (A) 400 to 1,000 ms, (B) 1,000 to 2,000 ms, and (C) 2,000 to 3,000 ms for the high-trait-anxious (HTA) and low-trait-anxious (LTA) groups in each condition. Panel A presents central-parietal LPP amplitude between 400 and 1,000 ms; Panel B presents central-parietal LPP amplitude between 1,000 and 2,000 ms; Panel C presents central-parietal LPP amplitude between 2,000 and 3,000 ms. Error bars represent standard errors of the mean. *** $p < .001$. ** $p < .01$. * $p < .05$. See the online article for the color version of this figure.

than for the LTA group at the preappraised neutral condition, $t(38) = 2.15$, $p = .038$, but not in the neutral condition or preappraised negative condition, $ts < 1.38$, $ps > .18$. There were also no significant intergroup differences between the preappraised negative condition and the neutral condition (HTA group: $M = 3.26$, $SD = 2.17$; LTA group: $M = 4.09$, $SD = 1.52$), $t(38) = 1.40$, $p = .17$.

Central-parietal LPP (1,000 to 2,000 ms). During the time window of 1,000 to 2,000 ms, both the main effect of condition, $F(2, 76) = 30.47$, $p < .001$, $\eta_p^2 = .445$, and the Group × Condition interaction, $F(2, 76) = 15.22$, $p < .001$, $\eta_p^2 = .286$, were significant. For the LTA group, the amplitude of the central-parietal LPP was higher for the preappraised negative condition than for both the preappraised neutral condition and the neutral condition ($ts > 8.13$, $ps < .001$), which did not differ from each other, $t(19) = 1.70$, $p = .106$. However, the HTA group showed a strikingly different pattern. The amplitude of the central-parietal LPP was higher for the preappraised neutral condition than for both the preappraised negative condition and the neutral conditions ($ts > 2.23$, $ps < .038$), whereas the amplitude in the preappraised negative condition was higher than was that in the neutral condition, $t(19) = 3.04$, $p = .007$. The HTA group therefore demonstrated an atypical pattern of enhanced central-parietal LPP for the preappraised neutral condition relative to the preappraised negative condition (see Figure 5).

In addition, during the time window of 1,000 to 2,000 ms, intergroup comparisons showed a more positive central-parietal LPP for the HTA group than for the LTA group in the preappraised neutral condition, $t(38) = 2.71$, $p = .01$, but not in the neutral condition or the preappraised negative condition ($ts < 1.02$, $ps > .32$). It is mportant to note that the results showed smaller central-parietal LPP differences between the preappraised negative condition and neutral condition in the HTA group ($M = 1.78$, $SD = 2.61$) than in the LTA group ($M = 3.55$, $SD = 1.66$), $t(38) = 2.56$, $p = .015$.

Central-parietal LPP (2,000 to 3,000 ms). During the time window of 2,000 to 3,000 ms, both the main effect of condition, $F(2, 76) = 25.80$, $p < .001$, $\eta_p^2 = .404$, and the Group × Condition interaction, $F(2, 76) = 5.87$, $p = .005$, $\eta_p^2 = .134$, were significant. For the LTA group, the amplitude of the central-parietal LPP was higher in both the preappraised negative and preappraised neutral conditions than in the neutral condition ($ts > 2.90$, $ps < .009$), whereas the amplitude of the preappraised negative condition was higher than was that of the preappraised neutral condition, $t(19) = 4.55$, $p < .001$. The HTA group also showed higher central-parietal LPP amplitude in both the preappraised negative and preappraised neutral conditions compared with the neutral condition ($ts > 3.27$, $ps < .004$); however, there was no difference between the two preappraised conditions, $t(19) = 1.48$, $p = .156$ (see Figure 5).

In addition, during the time window of 2,000 to 3,000 ms, there were no significant group differences in the amplitudes of central-parietal LPP in any conditions ($ts < 1.22$, $ps > .23$). However, there were smaller central-parietal LPP differences between the preappraised negative condition and the neutral condition in the HTA group (M = 1.90, SD = 2.60) than in the LTA group (M = 3.42, SD = 2.19), $t(38) = 1.99$, $p = .053$.

Correlations

Pearson's correlations were used to examine the relationship between self-rating scores in each condition and the electrophysiological index of directed reappraisal (i.e., central-parietal LPP difference scores, calculated by subtracting the preappraised neutral condition from the preappraised negative condition at each time window: 400 to 1,000 ms, 1,000 to 2,000 ms, and 2,000 to 3,000 ms). Higher central-parietal LPP difference scores reflect better regulation during directed reappraisal. In the LTA group, central-parietal LPP difference scores during the time window of 400 to 1,000 ms were positively associated with valence ratings in the preappraised neutral condition, Pearson's $r(20) = .46$, $p = .044$, indicating that better directed reappraisal was associated with lower unpleasantness in response to negative stimuli in the preappraised neutral condition. However, there were no significant correlations between the central-parietal LPP difference scores and self-report ratings in the HTA group (see Table 2).

Discussion

The present study used ERP to investigate whether HTA individuals can effectively use directed reappraisal to down-regulate neural responses to negative stimuli and the temporal dynamics of this process. As predicated, LTA individuals showed decreased central-parietal LPP amplitude in the preappraised neutral condition relative to the preappraised negative condition between 400- and 3,000-ms post picture onset. These findings are consistent with those of prior studies (Foti & Hajcak, 2008; MacNamara et al., 2009), suggesting that LTA individuals can effectively use directed reappraisal to down-regulate neural responses to negative stimuli. In contrast, HTA individuals not only showed parallel central-parietal LPP amplitudes for the two preappraised conditions during the time windows of 400 to 1,000 ms but also showed enhanced central-parietal LPP amplitudes in the preappraised neutral condition relative to the preappraised negative condition during the time window of 1,000 to 2,000 ms. These abnormal central-parietal LPP patterns not only verify that HTA individuals exhibit ineffective use of directed reappraisal to down-regulate neural responses to unpleasant stimuli but also reveal an abnormal time-course of directed reappraisal in such individuals.

Table 2
Correlations Between Self-Report Ratings and Central-Parietal LPP Difference Scores at Each Time Window for the High-Trait-Anxious (HTA) and Low-Trait-Anxious (LTA) Groups

	Time window					
	400 to 1,000 ms		1,000 to 2,000 ms		2,000 to 3,000 ms	
Condition	LTA	HTA	LTA	HTA	LTA	HTA
Self-report valence ratings						
Neutral	.37	.32	.43	.29	.26	.16
Preappraised neutral	.46*	−.10	.33	−.39	.09	−.22
Preappraised negative	.02	−.25	−.02	.01	−.48*	.01
Self-report arousal ratings						
Neutral	−.46*	.16	−.08	−.06	.20	−.39
Preappraised neutral	−.41	.04	−.12	.34	.27	−.14
Preappraised negative	−.30	.18	−.03	−.06	.32	−.18

* $p < .05$.

Consistent with our first hypothesis, LTA individuals showed decreased central-parietal LPP amplitude in the preappraised neutral condition relative to the preappraised negative condition in the 400- to 1,000-ms time window. Moreover, central-parietal LPP difference scores in this time window were positively associated with valence ratings in the preappraised neutral condition for LTA individuals. In contrast, HTA individuals displayed no central-parietal LPP differences between the two preappraised conditions, and showed no significant correlation between central-parietal LPP difference scores and self-report ratings of unpleasantness. As the early central-parietal LPP (<1000 ms) reflects attention allocation (Hajcak et al., 2014; Hajcak, MacNamara, & Olvet, 2010; Moser et al., 2014; Strauss et al., 2013), these findings suggest that directed reappraisal did not alter the initial attention allocation to negative stimuli in HTA individuals. In addition to the abnormality in the early central-parietal LPP, HTA individuals showed an atypical pattern of enhanced central-parietal LPP for the preappraised neutral condition relative to preappraised negative condition in the 1,000- to 2,000-ms time window. As the late central-parietal LPP (>1,000 ms) reflects elaborative processing and the appraisal of stimulus meaning (Hajcak et al., 2014; Hajcak, MacNamara, & Olvet, 2010; Moser et al., 2014; Strauss et al., 2013), the finding of enhanced central-parietal LPP suggests that, among HTA individuals, directed reappraisal did not guide them to appraise unpleasant pictures toward a positive meaning. Given the differential functional significance of early central-parietal LPP and late central-parietal LPP, these findings together reveal the abnormal time-course of directed reappraisal among HTA individuals.

Why did HTA individuals show such enhanced neural processing in the 1,000- to 2,000-ms time window and maintain this trend in the 2,000- to 3,000-ms time window? In the directed reappraisal task, neutral descriptions can shift appraisal of unpleasant pictures in a more positive direction in healthy adults (Foti & Hajcak, 2008; MacNamara et al., 2009; Mocaiber et al., 2011). However, HTA individuals tend to interpret moderate negative stimuli as more negative than do LTA individuals (Bishop, 2007; Blanchette & Richards, 2003; Gebhardt & Mitte, 2014). Negative interpretation biases thus might make it difficult for HTA individuals to process unpleasant pictures toward a positive direction in the preappraised neutral condition. Therefore, for the HTA individuals, the negative descriptions of the preappraised negative condition are congruent with the subjects' negative responses to the pictures, whereas in the preappraised neutral condition, an incongruity between the neutral descriptions and negative interpretation emerges. In this incongruent situation, HTA individuals might recruit more resources for attentional control to resolve the conflict caused by the incongruity, which leads to their enhanced central-parietal LPP in the preappraised neutral condition. This explanation is consistent with the finding that the conflict LPP, a centro-parietally distributed waveform, is larger in response to words that are semantically incongruous (vs. congruous) with the preceding information (Appelbaum, Meyerhoff, & Woldorff, 2009).

The present findings of HTA individuals partly converge with those of Moser et al. (2014), as both studies demonstrate the abnormalities of cognitive reappraisal in anxious individuals. However, there are obvious differences in the time-course of cognitive reappraisal abnormalities. In Moser et al.'s (2014) study, worriers exhibited enhancements in activity denoting the preparatory process and early attention allocation. In contrast, in our study, HTA individuals did not show enhanced preparation, as evidenced by the lack of difference in the SPN amplitude for unpleasant pictures preceded by negative or neutral descriptions. More notably, HTA individuals exhibited ineffective use of directed reappraisal to alter the early attention allocation to and later reinterpretation of negative stimuli. The most likely explanation for this discrepancy is the different experimental tasks. In Moser et al. (2014), participants voluntarily generated alternative interpretations for reappraisal of negative stimuli. The increased difficulty of such a task might instigate worriers to recruit the compensation mechanism (e.g., enhanced activity for the preparation process, and early attention allocation) during generation of alternative interpretations. However, in our directed reappraisal task, participants were directly guided by the descriptions for each picture toward a given understanding, which ruled out differences in task difficulty across conditions. This explanation was further supported by the different findings for the frontal LPP, which indexes cognitive effort (Moser et al., 2014; Shafir, Schwartz, Blechert, & Sheppes, 2015). Specifically, in our directed reappraisal task, participants showed similar cognitive effort for the two preappraised conditions, whereas in the self-generated reappraisal task of Moser et al. (2014), positive reappraisal was associated with enhanced cognitive effort relative to passive viewing of negative pictures. Extending on previous studies (Campbell-Sills et al., 2011; Moser et al., 2014), our findings verify that HTA individuals show an impaired ability to adaptively implement the reinterpretation of negative stimuli even in a directed reappraisal task, which is a relatively pure test of participants' reappraisal ability.

The present study provided electrophysiological evidence of emotion regulation abnormality during directed reappraisal in HTA individuals. Such an abnormality, however, did not emerge in the self-reported results, as the preappraisal manipulation was equally effective at decreasing negative emotional experience in both groups. Analogous findings using the same task were also observed in individuals with schizophrenia, whose emotion regulation abnormality during directed reappraisal were only evident at the electrophysiological level (Strauss et al., 2013). Thus, the central-parietal LPP may provide a more sensitive index of emotion regulation than might the self-report ratings. It was also notable that HTA individuals reported higher unpleasantness for the pictures than did the LTA individuals, suggesting that HTA individuals have a heightened baseline level of negative emotionality. These generally elevated levels of negative emotionality in HTA individuals might arise from their ineffective use of cognitive reappraisal in response to evocative stimuli.

In addition to emotion dysregulation, the HTA group showed abnormal emotional reactivity. Although both groups were sensitive to the emotional arousal of the stimuli, the HTA group showed a particularly reduced engagement in elaborative processing of unpleasant stimuli, as evidenced by the smaller central-parietal LPP differences between negatively described unpleasant pictures and neutral pictures during the 1000–3000-ms time windows. This observation seems consistent with the prior finding showing a diminished central-parietal LPP difference in individuals with generalized anxiety disorder (Weinberg & Hajcak, 2011). Our findings, together with those from previous literature (Holmes et al., 2008; Weinberg & Hajcak, 2011), point to the attentional avoidance of negative stimuli in anxious individuals at a later stage of processing. However, there is another possibility accounting for the smaller LPP differences in the HTA group. Prior studies have shown that HTA individuals show enhanced anticipatory response and reduced engagement to potentially negative stimuli (Simmons, Strigo, Matthews, Paulus, & Stein, 2006). In the current task, each description was given before participants viewed the corresponding picture. Presenting a description before the picture might alter HTA individuals' anticipatory response to the upcoming picture, which in turn might reduce their subsequent LPP responses to negative pictures. However, this explanation is unlikely because both groups exhibited similar anticipation of and preparation to the upcoming picture, as reflected by the lack of a Group × Description Type interaction for SPN amplitudes.

Several limitations of the present study should be noted. First, we confined our sample to female participants. Although this methodological approach effectively controls for gender differences in cognitive reappraisal (Domes et al., 2010), it limits the generalizability of the findings. Future studies could replicate the present findings among male samples or among samples with a balanced gender distribution. Second, the common problem in anxiety research lies in the potential impact of depression on the final results, as there is considerable comorbidity between anxiety and depression (Kessler et al., 2003). In the present study, when we used analysis of covariance on the central-parietal LPP amplitudes with condition and group as factors and depression scores as covariates, the interaction of condition and group was still significant during the time windows of 1,000 to 2000-ms, but not during the time windows of 400 to 1,000 ms and 2,000 to 3,000 ms. Therefore, it will be critical to find an effective way of examining the independent and interactive effects of anxiety and depression in relation to directed reappraisal. Third, the present results only show the abnormality of central-parietal LPP in HTA individuals during the down-regulation of negative emotion. However, given that cognitive reappraisal includes both down- and up-regulation of negative emotion, future researchers should investigate whether such abnormality is also observed when HTA individuals are asked to up-regulate negative emotion.

Although there are limitations in this study, our findings have important implications for the prevention of anxiety. Given that HTA individuals—who have a higher risk for anxiety disorders—exhibit a similar abnormality in cognitive reappraisal as patients with anxiety disorders, it is likely that emotion dysregulation plays an important role in the occurrence and development of anxiety disorders. As such, more attention should be paid to these high-risk individuals; after all, they are still a largely high-functioning student population. Furthermore, given that repeated reappraisal training can improve individuals' ability to down-regulate negative emotion (Denny & Ochsner, 2014), directed reappraisal should be repeatedly trained in HTA individuals to improve their cognitive reappraisal abilities and prevent the development of anxiety symptoms.

References

Amstadter, A. (2008). Emotion regulation and anxiety disorders. *Journal of Anxiety Disorders, 22,* 211–221. http://dx.doi.org/10.1016/j.janxdis.2007.02.004

Appelbaum, L. G., Meyerhoff, K. L., & Woldorff, M. G. (2009). Priming and backward influences in the human brain: Processing interactions during the Stroop interference effect. *Cerebral Cortex, 19,* 2508–2521. http://dx.doi.org/10.1093/cercor/bhp036

Ball, T. M., Ramsawh, H. J., Campbell-Sills, L., Paulus, M. P., & Stein, M. B. (2013). Prefrontal dysfunction during emotion regulation in generalized anxiety and panic disorders. *Psychological Medicine, 43,* 1475–1486. http://dx.doi.org/10.1017/S0033291712002383

Basten, U., Stelzel, C., & Fiebach, C. J. (2011). Trait anxiety modulates the neural efficiency of inhibitory control. *Journal of Cognitive Neuroscience, 23,* 3132–3145. http://dx.doi.org/10.1162/jocn_a_00003

Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. (1996). Comparison of Beck Depression Inventories -IA and -II in psychiatric outpatients. *Journal of Personality Assessment, 67,* 588–597. http://dx.doi.org/10.1207/s15327752jpa6703_13

Bishop, S. J. (2007). Neurocognitive mechanisms of anxiety: An integrative account. *Trends in Cognitive Sciences, 11,* 307–316. http://dx.doi.org/10.1016/j.tics.2007.05.008

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience, 12,* 92–98. http://dx.doi.org/10.1038/nn.2242

Bishop, S., Duncan, J., Brett, M., & Lawrence, A. D. (2004). Prefrontal cortical function and anxiety: Controlling attention to threat-related stimuli. *Nature Neuroscience, 7,* 184–188. http://dx.doi.org/10.1038/nn1173

Blanchette, I., & Richards, A. (2003). Anxiety and the interpretation of ambiguous information: Beyond the emotion-congruent effect. *Journal of Experimental Psychology: General, 132,* 294–309. http://dx.doi.org/10.1037/0096-3445.132.2.294

Buhle, J. T., Silvers, J. A., Wager, T. D., Lopez, R., Onyemekwu, C., Kober, H., . . . Ochsner, K. N. (2014). Cognitive reappraisal of emotion: A meta-analysis of human neuroimaging studies. *Cerebral Cortex, 24,* 2981–2990. http://dx.doi.org/10.1093/cercor/bht154

Campbell-Sills, L., Simmons, A. N., Lovero, K. L., Rochlin, A. A., Paulus, M. P., & Stein, M. B. (2011). Functioning of neural systems supporting emotion regulation in anxiety-prone individuals. *NeuroImage, 54,* 689–696. http://dx.doi.org/10.1016/j.neuroimage.2010.07.041

Cisler, J. M., & Olatunji, B. O. (2012). Emotion regulation and anxiety disorders. *Current Psychiatry Reports, 14,* 182–187. http://dx.doi.org/10.1007/s11920-012-0262-2

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods, 134,* 9–21. http://dx.doi.org/10.1016/j.jneumeth.2003.10.009

Denny, B. T., & Ochsner, K. N. (2014). Behavioral effects of longitudinal training in cognitive reappraisal. *Emotion, 14,* 425–433. http://dx.doi.org/10.1037/a0035276

Domes, G., Schulze, L., Böttger, M., Grossmann, A., Hauenstein, K., Wirtz, P. H., . . . Herpertz, S. C. (2010). The neural correlates of sex differences in emotional reactivity and emotion regulation. *Human Brain Mapping, 31,* 758–769. http://dx.doi.org/10.1002/hbm.20903

Eisenberg, N., Fabes, R. A., Guthrie, I. K., & Reiser, M. (2000). Dispositional emotionality and regulation: Their role in predicting quality of social functioning. *Journal of Personality and Social Psychology, 78,* 136–157. http://dx.doi.org/10.1037/0022-3514.78.1.136

Foti, D., & Hajcak, G. (2008). Deconstructing reappraisal: Descriptions preceding arousing pictures modulate the subsequent neural response. *Journal of Cognitive Neuroscience, 20,* 977–988. http://dx.doi.org/10.1162/jocn.2008.20066

Gebhardt, C., & Mitte, K. (2014). Seeing through the eyes of anxious individuals: An investigation of anxiety-related interpretations of emotional expressions. *Cognition and Emotion, 28,* 1367–1381. http://dx.doi.org/10.1080/02699931.2014.881328

Goldin, P. R., Manber, T., Hakimi, S., Canli, T., & Gross, J. J. (2009). Neural bases of social anxiety disorder: Emotional reactivity and cognitive regulation during social and physical threat. *Archives of General Psychiatry, 66,* 170–180. http://dx.doi.org/10.1001/archgenpsychiatry.2008.525

Gross, J. J. (Ed.). (2014). Emotion regulation: Conceptual and empirical foundation. *Handbook of emotion regulation* (2nd ed., pp. 3–20). New York, NY: Guilford Press.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85,* 348–362. http://dx.doi.org/10.1037/0022-3514.85.2.348

Hajcak, G., Dunning, J. P., Foti, D., & Weinberg, A. (2014). Temporal dynamics of emotion regulation. In J. J. Gross (Ed.), *Handbook of Emotion Regulation* (2nd ed., pp. 441–474). New York, NY: Guilford Press.

Hajcak, G., MacNamara, A., & Olvet, D. M. (2010). Event-related potentials, emotion, and emotion regulation: An integrative review. *Developmental Neuropsychology, 35,* 129–155. http://dx.doi.org/10.1080/87565640903526504

Hajcak, G., & Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective & Behavioral Neuroscience, 6,* 291–297. http://dx.doi.org/10.3758/CABN.6.4.291

Hoffmann, J., & Russ, S. (2012). Pretend Play, Creativity, and Emotion Regulation in Children. *Psychology of Aesthetics, Creativity, and the Arts, 6,* 175–184. http://dx.doi.org/10.1037/a0026299

Holmes, A., Nielsen, M. K., & Green, S. (2008). Effects of anxiety on the processing of fearful and happy faces: An event-related potential study. *Biological Psychology, 77,* 159–173. http://dx.doi.org/10.1016/j.biopsycho.2007.10.003

Horan, W. P., Hajcak, G., Wynn, J. K., & Green, M. F. (2013). Impaired emotion regulation in schizophrenia: Evidence from event-related potentials. *Psychological Medicine, 43,* 2377–2391. http://dx.doi.org/10.1017/S0033291713000019

Indovina, I., Robbins, T. W., Núñez-Elizalde, A. O., Dunn, B. D., & Bishop, S. J. (2011). Fear-conditioning mechanisms associated with trait vulnerability to anxiety in humans. *Neuron, 69,* 563–571. http://dx.doi.org/10.1016/j.neuron.2010.12.034

Jung, T. P., Makeig, S., Humphries, C., Lee, T. W., McKeown, M. J., Iragui, V., & Sejnowski, T. J. (2000). Removing electroencephalographic artifacts by blind source separation. *Psychophysiology, 37,* 163–178. http://dx.doi.org/10.1111/1469-8986.3720163

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Koretz, D., Merikangas, K. R., . . . the National Comorbidity Survey Replication. (2003). The epidemiology of major depressive disorder: Results from the National Comorbidity Survey Replication (NCS-R). *Journal of the American Medical Association, 289,* 3095–3105. http://dx.doi.org/10.1001/jama.289.23.3095

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual* (Tech. Rep. No. A-8). Gainesville, FL: University of Florida.

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: An open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience, 8,* 213. http://dx.doi.org/10.3389/fnhum.2014.00213

Macnamara, A., Foti, D., & Hajcak, G. (2009). Tell me about it: Neural activity elicited by emotional pictures and preceding descriptions. *Emotion, 9,* 531–543. http://dx.doi.org/10.1037/a0016251

Matsuda, I., & Nittono, H. (2015). Motivational significance and cognitive effort elicit different late positive potentials. *Clinical Neurophysiology, 126,* 304–313. http://dx.doi.org/10.1016/j.clinph.2014.05.030

Mocaiber, I., Sanchez, T. A., Pereira, M. G., Erthal, F. S., Joffily, M., Araujo, D. B., . . . de Oliveira, L. (2011). Antecedent descriptions change brain reactivity to emotional stimuli: A functional magnetic resonance imaging study of an extrinsic and incidental reappraisal strategy. *Neuroscience, 193,* 241–248. http://dx.doi.org/10.1016/j.neuroscience.2011.07.003

Moser, J. S., Hajcak, G., Bukay, E., & Simons, R. F. (2006). Intentional modulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology, 43,* 292–296. http://dx.doi.org/10.1111/j.1469-8986.2006.00402.x

Moser, J. S., Hartwig, R., Moran, T. P., Jendrusina, A. A., & Kross, E. (2014). Neural markers of positive reappraisal and their associations with trait reappraisal and worry. *Journal of Abnormal Psychology, 123,* 91–105. http://dx.doi.org/10.1037/a0035817

New, A. S., Fan, J., Murrough, J. W., Liu, X., Liebman, R. E., Guise, K. G., . . . Charney, D. S. (2009). A functional magnetic resonance imaging study of deliberate emotion regulation in resilience and posttraumatic stress disorder. *Biological Psychiatry, 66,* 656–664. http://dx.doi.org/10.1016/j.biopsych.2009.05.020

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences, 9,* 242–249. http://dx.doi.org/10.1016/j.tics.2005.03.010

Paul, S., Simon, D., Kniesche, R., Kathmann, N., & Endrass, T. (2013). Timing effects of antecedent- and response-focused emotion regulation strategies. *Biological Psychology, 94,* 136–142. http://dx.doi.org/10.1016/j.biopsycho.2013.05.019

Qi, S., Ding, C., & Li, H. (2014). Neural correlates of inefficient filtering of emotionally neutral distractors from working memory in trait anxiety. *Cognitive, Affective & Behavioral Neuroscience, 14,* 253–265. http://dx.doi.org/10.3758/s13415-013-0203-5

Rypma, B., Berger, J. S., & D'Esposito, M. (2002). The influence of working-memory demand and subject performance on prefrontal cortical activity. *Journal of Cognitive Neuroscience, 14,* 721–731. http://dx.doi.org/10.1162/08989290260138627

Schönfelder, S., Kanske, P., Heissler, J., & Wessa, M. (2014). Time course of emotion-related responding during distraction and reappraisal. *Social Cognitive and Affective Neuroscience, 9,* 1310–1319. http://dx.doi.org/10.1093/scan/nst116

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology, 37,* 257–261. http://dx.doi.org/10.1111/1469-8986.3720257

Seidel, E. M., Pfabigan, D. M., Hahn, A., Sladky, R., Grahl, A., Paul, K., . . . Lamm, C. (2015). Uncertainty during pain anticipation: The adaptive value of preparatory processes. *Human Brain Mapping, 36,* 744–755. http://dx.doi.org/10.1002/hbm.22661

Shafir, R., Schwartz, N., Blechert, J., & Sheppes, G. (2015). Emotional intensity influences pre-implementation and implementation of distraction and reappraisal. *Social Cognitive and Affective Neuroscience, 10,* 1329–1337. http://dx.doi.org/10.1093/scan/nsv022

Shek, D. T. (1993). The Chinese version of the State-Trait Anxiety Inventory: Its relationship to different measures of psychological well-being. *Journal of Clinical Psychology, 49,* 349–358. http://dx.doi.org/10.1002/1097-4679(199305)49:3<349::AID-JCLP2270490308>3.0.CO;2-J

Sheppes, G., & Gross, J. J. (2011). Is timing everything? Temporal considerations in emotion regulation. *Personality and Social Psychology Review, 15,* 319–331. http://dx.doi.org/10.1177/1088868310395778

Simmons, A., Strigo, I., Matthews, S. C., Paulus, M. P., & Stein, M. B. (2006). Anticipation of aversive visual stimuli is associated with increased insula activation in anxiety-prone subjects. *Biological Psychiatry, 60,* 402–409. http://dx.doi.org/10.1016/j.biopsych.2006.04.038

Spielberger, C. D. (1979). *Understanding stress and anxiety*. New York, NY: Harper & Rowe.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State–Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Strauss, G. P., Kappenman, E. S., Culbreth, A. J., Catalano, L. T., Lee, B. G., & Gold, J. M. (2013). Emotion regulation abnormalities in schizophrenia: Cognitive change strategies fail to decrease the neural response to unpleasant stimuli. *Schizophrenia Bulletin, 39,* 872–883. http://dx.doi.org/10.1093/schbul/sbs186

Thiruchselvam, R., Blechert, J., Sheppes, G., Rydstrom, A., & Gross, J. J. (2011). The temporal dynamics of emotion regulation: An EEG study of distraction and reappraisal. *Biological Psychology, 87,* 84–92. http://dx.doi.org/10.1016/j.biopsycho.2011.02.009

Weinberg, A., & Hajcak, G. (2011). Electrocortical evidence for vigilance-avoidance in generalized anxiety disorder. *Psychophysiology, 48,* 842–851. http://dx.doi.org/10.1111/j.1469-8986.2010.01149.x

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